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PERCEPTUAL DIMENSIONS OF VISUAL SCENES RELEVANT FOR SIMULATING LOW-ALTITUDE FLIGHT

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13. ABSTRACT (Maximum 200 words)

Multidimensional scaling was used to identify the features of real-world terrain that are salient to pilots during low-altitude flight. The subjects were pilots experienced flying in the Southwest United States (Experiment 1) and pilots experienced flying in Europe (Experiment 2). The stimuli were videotape segments (Dynamic Presentation) and still photographs (Static Presentation) depicting low-altitude flight over a variety of real-world terrains. Pilots rated pairs of terrains with respect to similarity of visual cues for low-altitude flight. Terrains were also rated on eight bipolar rating scales representing a variety of terrain characteristics thought to be of possible relevance to pilots. Similarity ratings were submitted to a multidimensional scaling analysis using the procedure ALSCAL. Two-dimensional solutions were deemed most appropriate in all cases. Bipolar ratings were submitted to a multiple regression analysis in which ratings on each scale were regressed over dimensional coordinates. Results of Experiment 1, Dynamic Presentation, revealed dimensions corresponding to 1) terrain contour, and 2) object size and spacing. Results for Static Presentation were less interpretable suggesting the possibility of a single dimension capturing the presence/absence of global scene detail. In Experiment 2, results for both presentation modes replicated Experiment 1, Dynamic Presentation, although the fit of the data remained superior with Dynamic Presentation. Taken together, these results provide consistent evidence that pilots flying at low altitudes perceive variation in terrain contour and object size and spacing. These features should, therefore, be emphasized in simulator scenes designed to support low-altitude flight.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

PREFACE

This effort was conducted in support of training research and development to maintain air combat readiness and, specifically, visual scene and display requirements.

This work was performed in support of Work Unit No. 1123-32-03, Tactical Scene Content Requirements, Principal Investigator, Dr. Elizabeth L. Martin, and 1123-03-85, Flying Training Research Support, Contract No. F33615-90-C-0005, Contract Monitor, Ms. Patricia A. Spears. One of the objectives of these work units is to identify flight simulator visual scene content factors that contribute to training effectiveness for low-altitude flight.

The author wishes to thank Mr DeForest Joralmon, who edited the videotapes and assisted with equipment setup; Mr Todd Baruch, who assisted with data entry; Drs Liz Martin, Celeste Howard, and Julie Lindholm, who provided helpful comments on an earlier draft of this report; and Ms Marge Keslin, who oversaw final editing.

PERCEPTUAL DIMENSIONS OF VISUAL SCENES RELEVANT FOR SIMULATING LOW-ALTITUDE FLIGHT

SUMMARY

Pilots flying at low altitudes rely heavily on out-of-the-cockpit visual cues. It is, therefore, important that visual scenes displayed to pilots in flight simulators contain relevant visual information. Multidimensional scaling was used in the present investigation to identify the salient features of real-world scenes. Pilots viewed videotape segments (Dynamic Condition) and still photographs (Static Condition) depicting low-altitude flight in a variety of real-world scenes. Results revealed that pilots were sensitive to variation in two scene characteristics: 1) terrain contour, and 2) object size and spacing. Variation in terrain contour was particularly salient with videotape segments, suggesting that motion affects perception of hills and ridges. Results were similar for pilots who routinely fly in desert environments and pilots who fly in Europe, suggesting that same scene characteristics are relevant across geographic regions.

These results suggest efforts to develop flight simulator visual scenes suitable for training low-altitude flight should focus on enhancing the perceptual fidelity of hills and ridges, and specifying the optimal size and spacing of vertical features positioned upon the terrain surface.

INTRODUCTION

Low-altitude, high-speed flight is inherently dangerous, accounting for a disproportionate number of mishaps given total number of hours spent flying in that arena (Academic Text: Low-Altitude Training, 1986). Flight simulators provide the possibility of enhancing pilot proficiency in this domain so that pilots are better prepared for the real-world flight environment. Pilots flying at low altitudes rely heavily on out-of-the-cockpit visual cues to control altitude and avoid contact with the terrain surface (Academic Text: Low-Altitude Training, 1986). It is, therefore, essential that flight simulator visual scenes contain relevant visual cues.

Changes in speed and altitude are detected with relatively impoverished simulator scenes consisting of simple grid patterns on flat terrain surfaces (Owen, Warren, Jensen & Mangold, 1981; Owen, Warren, Jensen, Mangold & Hettinger, 1981). Therefore, simulator scenes need not replicate the real-world to be effective. However, performance of a variety of simulated flight tasks improves with increases in scene complexity--that is, the number of lines, polygonal surfaces, etc., used to construct the scene (Barfield, Rosenberg & Kraft, 1989; Buckland, Edwards & Stephens, 1981; Lintern, Thomley-Yates, Nelson & Roscoe, 1987; Martin & Rinalducci, 1983). More important, performance varies as a function of specific features used in scenes. For example, altitude control is better with lines running parallel to the flight path than with lines running perpendicular to it (Wolpert, 1988). Estimation of impact point on final approach to a runway is better with a grid pattern on the runway than with a dot pattern (Reardon, 1988). Altitude control is better with vertical objects projecting upward from simulated terrain surfaces than with flat, two-dimensional shapes (Buckland et al, 1981; Martin & Rinalducci, 1983; McCormick, Smith, Lewandowski, Preskar & Martin, 1983). Detection of change in altitude improves with increases in object density but not with increases in the detail/realism of individual objects (Kleiss, Hubbard & Curry, 1989; Kleiss & Hubbard, 1991).

The term "feature" will be used hereafter to denote prominent aspects of terrain topography, objects on terrain surfaces, and other distinguishing characteristics. Identification of relevant simulator scene features by an ongoing process of experimental evaluation is laborious and time consuming. Kleiss (1990) approached the problem from a different perspective by first attempting to identify the features of real-world scenes that are salient to pilots. Pilots viewed videotape segments of low-altitude flight in a variety of real-world scenes, and rated pairs of scenes with regard to similarity of visual cues useful for low-altitude flight. Similarity ratings were submitted to a multidimensional scaling (MDS) analysis and a two-dimensional solution yielded dimensions interpreted to be: 1) terrain contour (i.e., presence/absence of hills, ridges, etc.) and 2) object size and spacing.

This method is efficient in that it identifies relevant features within the context of a large number of equally plausible alternatives. However, the generality of Kleiss' results may be questioned on two points. First, the relatively small number of stimuli (nine) limited the maximum number of dimensions that could reliably be extracted from the data. Therefore, other relevant features may exist which remained unidentified. Second, a high degree of variability in altitude and apparent speed across videotape segments may have adversely affected perception of various features. The present investigation attempts to replicate Kleiss' (1990) results using a larger stimulus set filmed under more controlled conditions of altitude and speed.

The videotape segments used by Kleiss (1990) contained at least some motion information, such as optical flow, that is present during actual low-altitude flight. A question with both practical and theoretical implications is the extent to which relevant visual cue information is dependent on motion. On the practical side, dynamic videotape is costly not only to obtain in terms of time and equipment, but also to present in an experimental setting. Use of still photographs would be considerably more efficient. In a flight simulator, for example, DeMaio, Rinalducci, Brooks and Brunderman (1983) found that flat geometric shapes coplanar with the terrain surface were effective as cues for altitude only when scenes were viewed dynamically, as though the subject were flying through the scene. Vertical objects, however, were effective as cues with either static or dynamic views of the scene. Thus, evaluation of vertical objects, at least, would seem to be possible with more efficient static presentation of scenes.

On the theoretical side, researchers (e.g., Harker & Jones, 1980) have distinguished between two types of cues for depth in an image: 1) Static, such as linear perspective, gradient of texture size and density, interposition of near and far objects, etc., and 2) Dynamic, such as optical flow and accretion and deletion of background features by interposing surfaces. The question of whether scene features provide motion information is of concern in that consideration will have to be given to displaying that information in simulator scenes.

In an attempt to establish the relative roles of static and dynamic visual cue information, stimuli in the present investigation were presented statically in the form of still photographs and dynamically in the form of videotape segments of flight through the same real-world scenes.

EXPERIMENT 1

Method

Subjects and Design

The subjects were 14 F-16 and A-10 instructor pilots (IPs) from the 162d Tactical Fighter Group, Arizona Air National Guard, Tucson, AZ; 1 F-5 IP from the 425th Tactical Fighter Training Squadron, United States Air Force (USAF), Williams AFB, AZ; and 1 USAF pilot assigned to the Aircrew Training Research Division/ Armstrong Laboratory, Williams AFB, AZ, who had previously flown the F-111 aircraft. Missions for all aircraft types require low altitude flight.

Because time did not allow each subject to view both videotape segments and still photographs, subjects were randomly assigned to one of two groups: Dynamic Presentation, which viewed videotape

segments, and <u>Static Presentation</u>, which viewed still photographs. Since presentation of videotape segments required more viewing time than still photographs, each subject in the Dynamic Presentation condition viewed only a subset of possible stimuli (following an "incomplete data" design; Schiffman, Reynolds & Young, 1981). Ten subjects (mean total flying hours = 4170, SD = 1587, Range = 4400) were assigned to Dynamic Presentation and six (mean total flying hours = 3642, SD = 1902, Range = 5700) were assigned to Static Presentation. Mean total flying hours did not differ significantly between groups.

Stimuli and Materials

Scenes were photographed from a T-33 jet aircraft with a 16 mm motion picture camera mounted in the nose section and a 35 mm still camera mounted in a wing pod. The motion picture camera ran at thirty frames per second and was equipped with a 12.5 mm wide-angle lens which provided a 44.6° horizontal by 32° vertical view of the scene. The still camera was equipped with a standard 50 mm lens. Both cameras were canted down slightly so that the horizon filled approximately the top one-quarter of the scene. A radar altimeter was mounted in a second wing pod to monitor altitude during filming.

A list of specific terrains was compiled which encompassed as wide a variety of scene features as possible within the geographic region surrounding Mojave, CA, where flights originated. A 30-second pass was made over each terrain while maintaining altitude as close to 125 feet above ground level (AGL) and airspeed as close to 350 knots as conditions would allow. Thirty seconds of film and several still photographs were shot during each pass.

Motion picture film was transferred to videotape and sped up to produce the appearance of high-speed flight. An error in this process resulted in a higher than anticipated final speed of approximately 630 knots. Although this is not beyond the capability of many modern jet fighters, 400-500 knots is typical of most training missions. As the high speed was not detected until after data collection had begun, it was retained throughout Experiment 1. Due to the relatively high speed at which initial filming occurred, the increase in video speed did not appear to exaggerate effects of wind buffeting and minor positional adjustments.

Seventeen 5-second duration videotape segments depicting a wide variety of scene features were selected for use in the Dynamic Presentation condition. Seventeen segments yield a total of 136 unique stimulus pairings which, according to Kruskal and Wish (1978), are sufficient to reveal up to four dimensions if that level of structure is present in the data. A frame from each segment is shown in Appendix A. Stimulus pairs were randomly assigned to one of two subsets with the constraint that each

individual scene appeared approximately equally often in each subset and no individual scene appeared in consecutive pairs. As stimulus segments were arranged sequentially on videotape, two additional subsets were constructed in a similar fashion except that the order of scenes in each pair was reversed. A number preceded each stimulus pair, indicating the position of that pair in the sequence (1 through 68). A 1-second blank separated each segment within a pair and a 3-second blank followed each pair providing time to enter responses. No problems due to the rapid pace of videotape presentation were encountered.

Sixteen 6-1/2 by 10-inch still photographs of the same scenes used in Dynamic Presentation were selected for Static Presentation. The shore approach (see Appendix A) was eliminated in order to reduce the total number of stimulus pairs to 120. The smaller stimulus set and inherently faster pace of viewing still photographs allowed each subject to view all 120 pairs in a single session. Two complete sets of stimulus pairs were arranged in ring binders such that each photograph in a pair appeared on facing pages. The order of photographs for each pair was reversed between sets. Due to the large number of photographs, 2 ring binders were required to accommodate all 120 stimulus pairs. Stimulus pairs were randomly assigned to each binder with the constraint that each individual scene appeared approximately equally often in each binder. The order of pairs within binders was randomized with the constraint that no individual scene appeared in consecutive pairs. The pairs in each set were numbered sequentially 1 through 120.

Following Schiffman, Reynolds and Young (1981), similarity judgments were recorded on 120 mm lines anchored at the left with "exact same" and at the right with "completely different." Similarity ratings scales were arranged in a booklet containing four scales per page, each numbered in sequence. An instruction page appeared at the front of the booklet which described the purpose of the experiment and the rating procedure. A copy of this page is shown in Appendix B.

Eight 120 mm bipolar scales were included for each scene at the end of the booklet which reflected a variety of attributes thought to be relevant to pilots. The eight scales for a given scene appeared on a single page and were anchored at each end with the following dichotomous labels: 1) "Prefer" versus "Not prefer," 2) "Hilly/mountainous" versus "Flat," 3) "Objects" versus "No objects," 4) "Known size references" versus "No known size references," 5) "Texture/detail" versus "No texture/detail," 6) "Complex" versus "Simple," 7) "Regular" versus "Random," and 8) "High contrast" versus "Low contrast." These terms will be explained in greater detail later.

Procedure

Data were collected in small groups of one to four subjects. Subjects began by reading the instruction sheet provided at the front of the response booklet. It was emphasized that judgments should be based on how similar scenes appeared to pilots with regard to features they would attend to during actual low-altitude flight. No specific examples were mentioned so as to avoid influencing subjects' ratings. Subjects were encouraged to use the entire range available on the rating scales. To familiarize subjects with the range of stimuli used in the investigation, scenes were shown individually prior to presentation of stimulus pairs.

Videotapes were displayed on standard video monitors available in squadron briefing rooms. Approximately equal numbers of subjects viewed each of the four subsets of videotape segments and each of the two sets of still photographs. Half of the subjects viewing still photographs began with the first half of the set (pairs 1 through 60) and half began with the second half (pairs 61 through 120). In this way, up to four subjects could view still photographs simultaneously.

Upon completion of similarity ratings, subjects rated each individual scene on the eight bipolar attribute scales. First, subjects reviewed the anchor labels so that ambiguities regarding the meanings of the anchors could be clarified. Pilots are familiar with a majority of these terms as a result of training received during the normal course of their duties. When questions arose, the following definitions were provided: 1) "Prefer" versus "Not prefer" - preference for visual cues in a given scene, 2) "Hilly/mountainous" versus "Flat" - presence/absence of hills and/or mountains, 3) "Objects" versus "No objects" - presence/absence of discernible objects, 4) "Known size references" versus "No known size references" - extent to which apparent size of familiar features is available as a cue for distance, 5) "Texture/detail" versus "No texture detail" - extent to which the visibility of detail is available as a cue for distance (i.e., detail becomes more discernible as distance decreases), 6) "Complex" versus "Simple" - cluttered or noisy appearance of scene, 7) "Regular" versus "Random" - extent to which spacing or positioning of scene features is orderly and predictable, and 8) "High contrast" versus "Low contrast" - extent to which features stand out against the background, either light on dark or dark on light. Subjects viewed scenes one at a time and completed all eight bipolar scales before progressing to the next scene. The entire session took approximately 1 hour.

Results

Data for all analyses were distances in millimeters measured from the left end of each rating scale to the point at which the

subject marked the scale. Values ranged from 0 to 120. For pairwise ratings, larger values indicated greater dissimilarity. For bipolar ratings, larger values corresponded to the right anchor label.

Multidimensional Scaling Analysis

Pairwise ratings were submitted to a multidimensional scaling analysis using ALSCAL for PCs (Young, Takane & Lewyckyj, 1978). A nonmetric approach was used which assumes that similarity ratings are ordinal. A weighted (individual differences) approach was used because each subject provided a data matrix. Schiffman, Reynolds and Young (1981) note that this approach not only yields the most robust and reliable results, but because spatial configurations are not subject to rotation, they are also directly interpretable. Ratings were assumed to be continuous.

ALSCAL provides two measures of fit between a spatial configuration in a given dimensionality and the original similarity data: stress and RSQ. Stress is the discrepancy between Euclidian distances in the spatial configuration and measures of similarity among stimuli derived by MDS from the original data; smaller stress corresponds to better fit. RSQ is the squared correlation between Euclidian distances and measures of similarity.

Several methods and rules of thumb exist for identifying correct dimensionality--that is, dimensionality with maximum structure--and most involve examination of stress. Kruskal and Wish (1978) suggest that correct dimensionality is that at which stress becomes sufficiently small, .100 or less. Also, if stress values are plotted as a function of increasing dimensionality, an "elbow" in the curve at a given dimensionality may be taken to indicate maximum structure as higher dimensions add little additional structure. However, Isaac and Poor (1974) note that even small amounts of error or noise in the data inflate stress values and can mask evidence of an elbow. They suggest a method based on the simple idea that error is minimized at the dimensionality with maximum structure. Correct dimensionality, then, is that at which stress from experimental data differs most from stress obtained from purely random data (i.e., data with 100% error).

Figure 1 shows stress values and proportions of accounted variance for Dynamic and Static Presentation, plus stress for random data (Isaac & Poor, 1974, Table 4), as a function of dimensionality. Experimental data have no stress values for one-dimensional solutions because ALSCAL does not compute a one-dimensional solution with a weighted (individual differences) approach. Stress for random data is based on a stimulus set size of 16 stimuli because no values are available for stimulus sets of 17 stimuli. Note first that stress is consistently smaller and

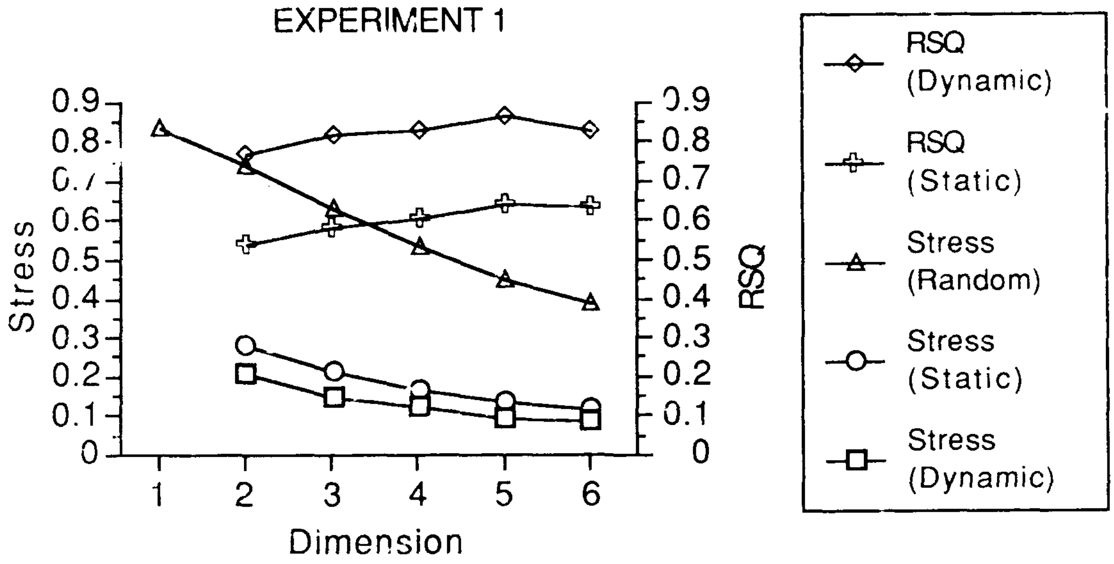


Figure 1. Stress and Proportion of Accounted Variance for Dynamic and Static Presentation and Stress for Random Data as a Function of Dimension: Experiment 1.

proportion of accounted variance is consistently larger for Dynamic than for Static Presentation, indicating generally better fit of the data for Dynamic Presentation. There is no evidence of an elbow in the plot of stress values for either Dynamic or Static Presentation, and stress remains relatively large even at the higher dimensionalities. However, the difference between stress for experimental data and stress for random data is largest at dimensionality equal to two for both presentation modes. Using Isaac and Poor's criterion, correct dimensionality would be two, or at least not greater than two. One-dimensional solutions cannot be ruled out although previous evidence of multidimensional structure with videotape presentation (Kleiss, 1990) argues against this possibility.

The numerical order of dimensions, first versus second, etc., does not necessarily indicate the importance of dimensions. However, a feature of ALSCAL output provided only with an individual differences approach is subject weights, which reflect the relative importance of each dimension to each individual subject. Squared subject weights sum to RSQ for individual subjects and provide an estimate of variance (in similarity ratings) explained by each dimension for a given subject. Nygren (1990) suggests that averaging squared subject weights across subjects provides an estimate of variance explained by each

dimension for the group. He cautions that since the data are ordinal in nature and do not satisfy the metric properties that underlie usual interpretations of variance, these estimates must be taken as approximations. Table 1 shows average squared subject weights for Dimensions 1 and 2 for Dynamic and Static Presentation respectively. For both presentation modes, values are largest for Dimension 1.

Table 1. Means of Squared Subject Weights for Dimensions 1 and 2: Experiment 1

Presentation Mode	Dimension 1	Dimension 2
Dynamic	.524	.242
Static	.350	.189

Multiple Regression Analysis of Bipolar Ratings

Bipolar ratings were analyzed using a multiple regression approach suggested by Kruskal and Wish (1978). Ratings for each scene on each of the eight bipolar scales were averaged across subjects. Mean ratings for each scale were regressed on dimensional coordinates for scenes derived from the two-dimensional ALSCAL solutions. Kruskal and Wish (1978) recommend that a bipolar attribute scale may provide a satisfactory interpretation of a dimension if 1) the multiple correlation for the scale is statistically reliable and large (.90's are good, but .80's and .70's may suffice), and 2) the regression weight for that dimension is comparatively large indicating a close relationship between rated increase in the attribute and ordering of stimuli along the dimensional axis.

Tables 2 and 3 show regression weights and multiple correlations for the eight bipolar attribute scales for Dynamic and Static Presentation respectively. Anchor labels corresponding to the left (i.e., numerically smallest) end of each bipolar scale are shown for identification. Dimensional polarity is arbitrary so stimulus coordinates were scaled so that anchor labels, which generally reflect the presence of particular attributes, are associated with positive dimensional coordinates. Regression weights in these cases were negative. Regression weights have been converted to direction cosines by normalizing so that they sum to one when squared. In this way, a "property vector" reflecting the direction through multidimensional space that best fits rated increase in the amount of an attribute can be positioned within derived spatial configurations.

Table 2. Results of Multiple Regression Analyses of Bipolar Ratings for Dynamic Presentation: Experiment 1

Scale	Regression Weights		Multiple R
	Dimension 1	Dimension 2	
1. Prefer	-.135	-.991	.933*
2. Hilly/mountainous	-.956	.294	.859*
3. Objects	-.326	-.945	.957*
4. Known size references	-.273	-.962	.930*
5. Texture/detail	-.357	-.934	.923*
6. Complex	-.775	-.632	.894*
7. Regular	.999	.040	.451 n.s.
8. High contrast	-.437	-.899	.913*

* $p < .001$

Table 3. Results of Multiple Regression Analyses of Bipolar Ratings for Static Presentation: Experiment 1

Scale	Regression Weights		Multiple R
	Dimension 1	Dimension 2	
1. Prefer	-.589	-.808	.882*
2. Hilly/mountainous	-.755	.656	.888*
3. Objects	-.904	-.427	.861*
4. Known size references	-.880	-.476	.804*
5. Texture/detail	-.717	-.697	.939*
6. Complex	-.956	.292	.944*
7. Regular	.314	-.949	.477 n.s.
8. High contrast	-.754	-.657	.860*

* $p < .001$

Inspection of Tables 2 and 3 shows that multiple Rs for all but the "Regular" scales are large and statistically highly reliable. For Dynamic Presentation (Table 2), only the "Hilly/ mountainous" scale has a large regression weight for Dimension 1 coordinates. Several scales have comparatively large regression weights for Dimension 2. The three largest are: a) "Prefer," b) "Known size references," and c) "Objects."

For Static presentation (Table 3), three scales have comparatively large regression weights for Dimension 1 coordinates: a) "Objects," b) "Known size references," and c) "Complex." The largest regression weight for Dimension 2 coordinates is for the "Prefer" scale.

Spatial Configurations

Dynamic Presentation. Figure 2 shows the two-dimensional spatial configuration for Dynamic Presentation. Axes reflect the range of coordinate values for each dimension. Line segments define the end points of property vectors for attribute ratings with largest regression weights in Table 2. Examination of Figure 2 reveals that scenes are clustered into three somewhat distinct groups. At the right of the spatial configuration are the Ridges, Barren Hills, Hills w/Trees, Valley, and Forested Mountain scenes which contain hills and ridges. At the top of the spatial configuration are the Airport, Dense Trees, and Trees/Pasture scenes which contain clusters of tall trees or large buildings. Remaining scenes are distributed across the lower-left quadrant of the spatial configuration and show an increase in vegetation distributed evenly on terrain surfaces as one proceeds upward from the bottom of Dimension 2.

Orientation of the "Hilly/mountainous" property vector with Dimension 1 supports the observation that this dimension captures some aspect of terrain contour. Some scenes at the "Flat" end of the dimension (e.g., Shore Approach, Dry Lake, and Desert) contain large mountains occluding the horizon whereas some scenes at the "Hilly" end (e.g., Barren Hills, Hills w/Trees) contain no large vertical obstructions. Dimension 1, therefore, appears to capture undulations in the terrain surface caused by small hills and ridges rather than large scale changes in terrain surface orientation or presence vertical obstructions.

Orientation of property vectors for "Known size references" and "Objects" with Dimension 2 supports the observation that this dimension captures some aspect of the presence of objects. Man-made objects and/or linear boundaries are not critical as there are few of these in Dense Trees and Trees/Pasture scenes whereas the Agricultural scene with linear field boundaries is positioned near the middle of the dimension. A high density of objects, per se, is not critical as the Desert w/Trees, Hills w/Trees, and Desert scenes are rich in vegetation, but are also positioned near the middle of the dimension. The clusters of trees in the Dense Trees and Trees/Pasture scenes, and the large buildings in the Airport scene extend vertically above the terrain surface and horizontally over a greater surface area than individual trees and bushes. Spaces delineating these features also tend to be large.

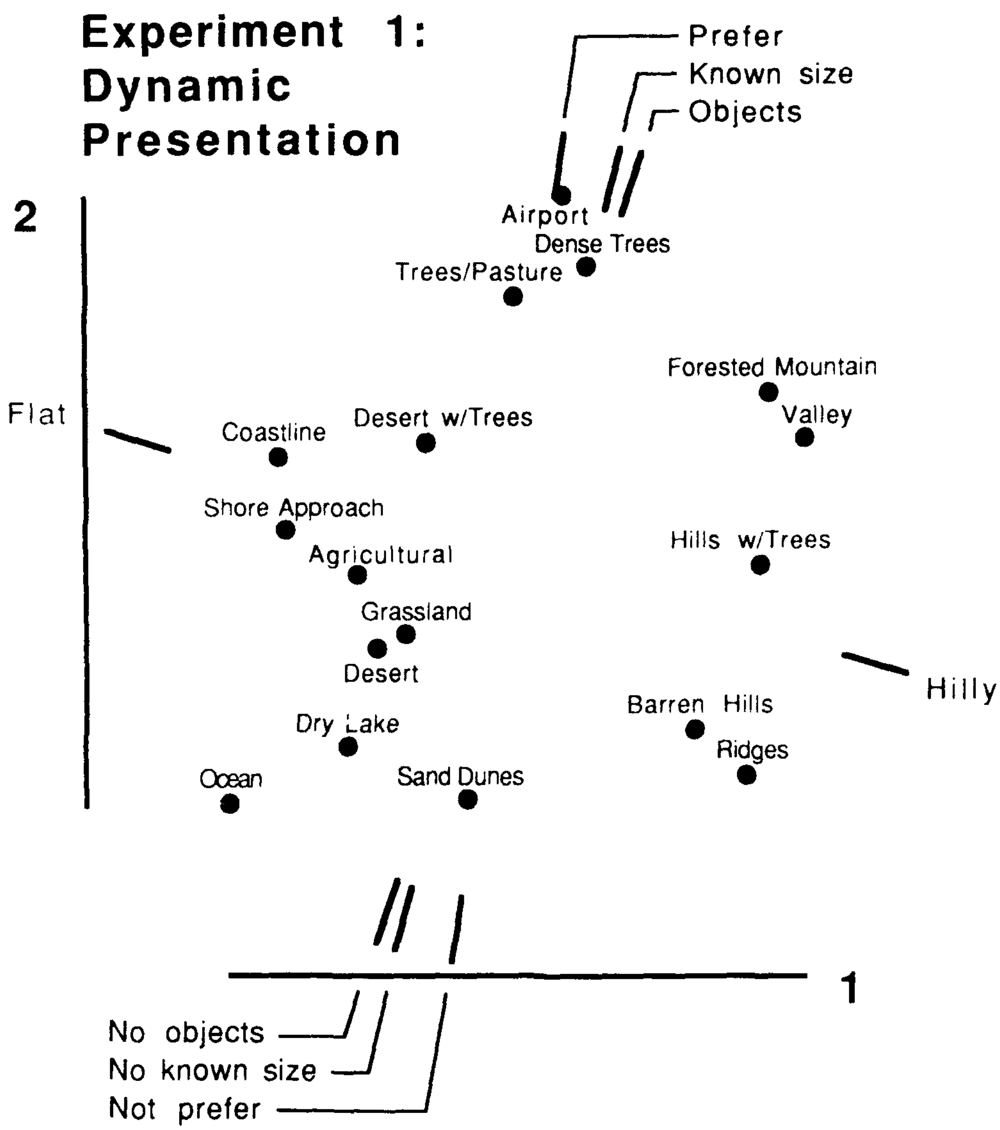


Figure 2. Two-Dimensional Spatial Configuration for Dynamic Presentation: Experiment 1.

Dimension 2, therefore, may be best characterized as capturing a composite of object size and spacing. A uniform distribution of small objects is useful, but large, spatially distinct objects are optimal. The "Preference" property vector indicates that these features are preferred by pilots to the hills and ridges (Dimension 1).

Static Presentation. Figure 3 shows the two-dimensional spatial configuration for Static Presentation. Axes reflect the range of coordinate values for each dimension. Line segments define the end points of property vectors for attribute ratings with largest regression weights in Table 2. Results of multiple regression analyses suggest differences between presentation modes which are evident in the spatial configuration for Static Presentation in Figure 3. Specifically, there is no clear ordering of scenes relative to the features identified in Figure 2 for Dynamic Presentation. Scenes at the left end of Dimension 1 are generally devoid of features whereas scenes at the right contain both objects and hills. Approximate orientation of property vectors for "Known size references," "Objects" and "Complexity" with Dimension 1 supports the observation that this dimension captures presence/absence of scene features. However, none of these property vectors are closely aligned with the dimensional axis so the attributes do not accurately describe the feature(s) captured by Dimension 1. There is no pattern evident in the positioning of scenes along Dimension 2 although the "Prefer" property vector is roughly aligned with this dimension. The composite nature of Dimension 1 and the absence of meaningful structure for Dimension 2 suggests the data for Static Presentation may actually be one-dimensional.

Discussion

Results for Dynamic Presentation essentially replicate those of Kleiss (1990) that pilots flying at low altitudes are sensitive to variation in two types of scene features: 1) terrain contour and 2) object size and spacing. Because present results were obtained with a different and more controlled stimulus set, they appear to be robust across a wide range of stimulus variation. Lack of evidence for higher dimensionality with this larger stimulus set argues that two dimensions are sufficient to describe the data.

In light of the consistency across stimuli with dynamic videotape presentation, the lack of interpretable structure for Static Presentation (plus the poorer fit of the data) suggests that still photographs are deficient in visual information specifying relevant scene features. The apparent superiority of Dynamic Presentation suggests that motion is important for perception of at least some relevant scene features. The absence of interpretable structure for Static Presentation precludes meaningful comparison between presentation modes for the purpose of localizing the effect of motion.

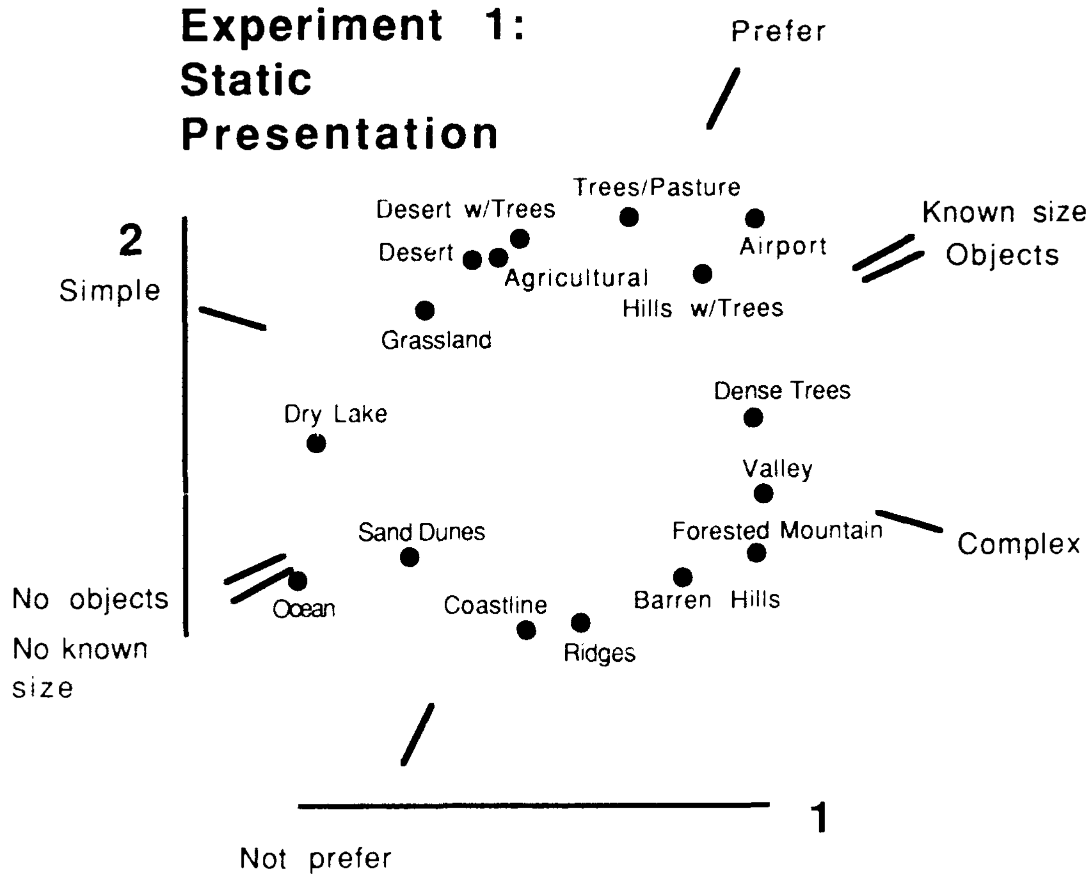


Figure 3. Two-Dimensional Spatial Configuration for Static Presentation: Experiment 1.

For Dynamic Presentation, ratings of preference were associated with Dimension 2, suggesting that large, spatially distinct objects provide the best cues. Despite the apparent importance of objects, Dimension 1 (terrain contour) accounted for most variance in pilots' ratings (Table 1). Therefore, the most salient scene feature (hills and ridges) was not the preferred scene feature (objects). One possibility is that rather than conceptualizing flat scenes in terms of the absence of hills and ridges, it may be more appropriate to conceptualize them in terms of the presence of a different type of feature. For example, flat terrain provides a continuous gradient of texture size and density whereas hilly terrain provides a discontinuous gradient. The

difference between these two types of features may be very salient to pilots, perhaps mediating important differences in workload or visual strategy, even though neither type is preferred.

EXPERIMENT 2

Pilots in Experiment 1, and most pilots in the Kleiss (1990) investigation, were stationed in the southwest United States and experienced flying in desert-type environments. The present pattern of results appears to be robust within that population. One question concerns whether pilots with experience flying in different geographic regions are sensitive to the same scene features. To investigate this possibility, subjects for Experiment 2 were selected from a population of pilots stationed in Europe. If pilots who routinely fly in European environments are sensitive to fundamentally different types of visual cues, spatial configurations for them will differ from those in Experiment 1.

Method

Subjects and Design

The subjects were 32 mission qualified pilots in the United States Air Force in Europe (USAFE). Fourteen were F-16 pilots from the 86 Tactical Fighter Wing (TFW), Ramstein AB, Germany; 14 were F-4 and F-16 pilots from the 52 TFW, Spangdahlem AB, Germany; and 4 were RF-4 pilots from the 26 Tactical Reconnaissance Wing (TRW), Sweibruken AB, Germany. Mission requirements for all pilots included low-altitude, high-speed flight. Nine pilots from the 86 TFW were assigned to the Static Presentation condition and the remaining 23 pilots were assigned to the Dynamic Presentation condition. Mean total hours flying time for Static Presentation was 896 (SD = 649, Range = 1,630) and for Dynamic Presentation was 1,329(SD = 702, Range = 2,150). Mean flying hours did not differ significantly between groups.

Stimuli and Materials

Stimuli were identical to Experiment 1 with two exceptions: a) The apparent speed depicted in videotape segments was reduced to approximately 420 knots (segments remained 5 seconds in duration). b) The Forested mountain videotape segment was replaced with a segment obtained from Air Force files which depicted more undulating terrain and a thick canopy of trees with no clearings. This segment, also called Forested mountain, is shown in Appendix C.

Procedure

The procedure was identical to Experiment 1.

Results

Data for all analyses were distances in millimeters measured from the left end of each rating scale to the point at which the subject marked the scale and ranged from 0 to 120.

Multidimensional Scaling Analysis

Pairwise ratings were submitted to a multidimensional scaling analysis using ALSCAL for PCs (Young, Takane & Lewyckyj, 1978). A nonmetric, weighted (individual differences) approach was used and tied scores were untied by ALSCAL.

Figure 4 shows stress values and proportions of accounted variance for Dynamic and Static Presentation, and stress for random data published by Isaac and Poor (1974, Table 4) as a function of dimensionality. Stress is consistently smaller and proportion of accounted variance is consistently larger for Dynamic than for Static Presentation. Proportion of accounted variance is particularly small for Static Presentation. The difference between obtained stress and random stress is again largest at dimensionality equal to two for both presentation conditions.

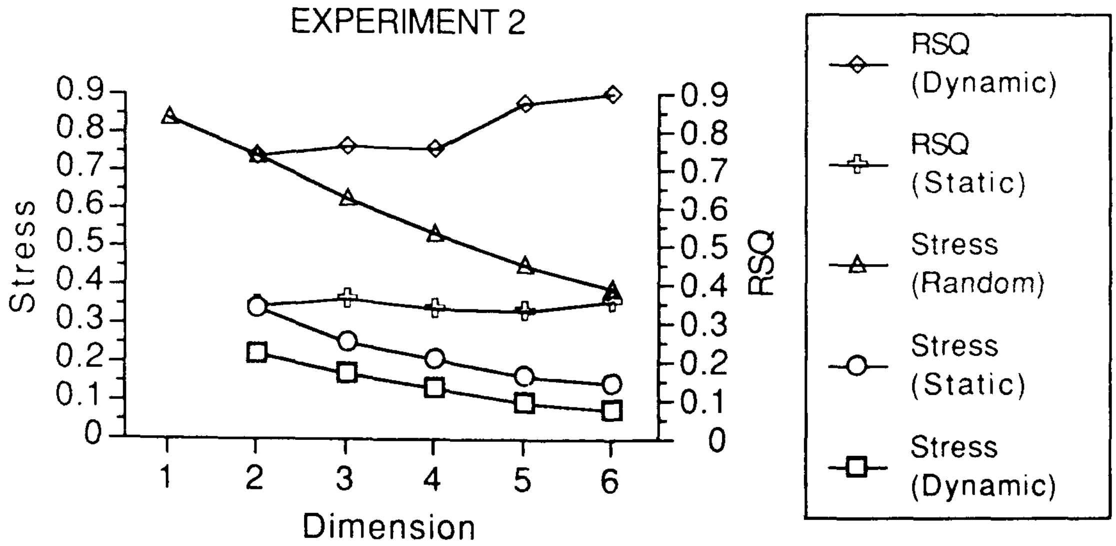


Figure 4. Stress and Proportion of Accounted Variance for Dynamic and Static Presentation and Stress for Random Data as a Function of Dimension: Experiment 2.

Table 4 shows means of squared subject weights for Dimensions 1 and 2 for Dynamic and Static Presentation respectively. For Dynamic Presentation, the value is largest for Dimension 1 whereas for Static Presentation, the values are nearly equal favoring Dimension 2 by a small amount.

Table 4. Means of Squared Subject Weights for Dimensions 1 and 2: Experiment 2

Presentation Mode	Dimension 1	Dimension 2
Dynamic	.461	.275
Static	.168	.176

Multiple Regression Analyses of Bipolar Ratings

Ratings for each scene on each of the eight bipolar scales were averaged across subjects. Mean ratings for each scale were regressed on dimensional coordinates for scenes derived from the two-dimensional ALSCAL solutions. Tables 5 and 6 show regression weights and multiple correlations for the eight bipolar attribute scales for Dynamic and Static Presentation respectively. Anchor labels corresponding to the left (numerically smallest) end of each bipolar scale are shown for identification. Dimensional coordinates were scaled so that anchor labels for bipolar scales with large regression weights on a given dimension were for the most part associated with positive dimensional coordinates. The exception was the "Regular" scale which had a positive weight indicating this attribute is associated with negative dimensional coordinates. Regression weights have been converted to direction cosines.

Multiple Rs for all analyses are large and statistically reliable. Results for Static Presentation (Table 6) appear more similar to Dynamic Presentation (Table 5) than in Experiment 1. For both presentation modes, the largest regression weight for Dimension 1 coordinates is for the "hilly/mountainous" scale. For Dynamic Presentation, the regression weight for Dimension 1 coordinates is also large for the "regular" scale. For Dynamic Presentation, the three largest regression weights for Dimension 2 coordinates are for the "preference," "known size references," and "objects" scales. For Static Presentation, the three largest regression weights are for the "objects," "known size references," and "high contrast" scales. Ratings of preference are not as strongly associated with Dimension 2 for Static Presentation.

Table 5. Results of Multiple Regression Analyses of Bipolar Ratings for Dynamic Presentation: Experiment 2

Scale	Regression Weights		Multiple R
	Dimension 1	Dimension 2	
1. Prefer	0.015	-1.000	.938**
2. Hilly/mountainous	-0.997	-0.072	.982**
3. Objects	-0.079	-0.997	.869**
4. Known size references	0.015	-1.000	.877**
5. Texture/detail	-0.138	-0.990	.911**
6. Complex	-0.703	-0.711	.874**
7. Regular	0.9840	.179	.732*
8. High contrast	0.163	-0.987	.889**

* $p < .01$
** $p < .001$

Table 6. Results of Multiple Regression Analyses of Bipolar Ratings for Static Presentation: Experiment 2

Scale	Regression Weights		Multiple R
	Dimension 1	Dimension 2	
1. Prefer	0.161	-0.987	.796**
2. Hilly/mountainous	-0.919	-0.395	.909**
3. Objects	-0.077	-0.997	.830**
4. Known size references	-0.099	-0.995	.852**
5. Texture/detail	-0.166	-0.986	.871**
6. Complex	-0.551	-0.835	937**
7. Regular	0.803	0.596	.755*
8. High contrast	0.114	-0.993	.933**

* $p < .01$
** $p < .001$

Spatial Configurations

Figures 5 and 6 show two-dimensional spatial configurations for Dynamic and Static Presentation respectively. Axes reflect the range of coordinate values for each dimension. Line segments define the end points of property vectors for attribute ratings with largest regression weights in Tables 5 and 6. Spatial configurations for both presentation modes are similar in major respects to Experiment 1, Dynamic Presentation (Figure 2). The Valley, Hills/Trees, Barren Hills, Forested Mountain, and Ridges scenes are positioned at the extreme right end of Dimension 1 and the Airport, Dense Trees, and Trees/Pasture scenes are positioned at the extreme top end of Dimension 2. Property vectors aligned with dimensional axes generally support dimensional interpretations similar to Experiment 1, Dynamic Presentation.

At a more subtle level, for Dynamic Presentation the Desert w/Trees, Agricultural, Grassland, and Desert scenes are clustered nearer the Airport, Dense Trees, and Trees/Pasture scenes and farther from the scenes with few visible features. Perception of these scenes may have been facilitated by the slower apparent speed of the videotape segments in the present experiment compared to Experiment 1. The Forested Mountain scene, which lacked clearings compared to the one used in Experiment 1, is now positioned nearer scenes with no objects providing additional evidence that open spaces delineating regions of dense trees are a source of useful information to pilots.

For Static Presentation, the Desert and Desert w/Trees scenes are positioned nearer featureless scenes at the lower end of Dimension 2, whereas the Coastline is positioned nearer scenes with large objects at the upper end of Dimension 2. The poorer fit of the spatial configuration to the rating data for Static Presentation suggests that the information content of still photographs remains inferior to videotape despite similar dimensional structures. The discrepancies noted above may simply reflect the relative lack of information for discriminating among various scenes.

Discussion

Comparable dimensional structures between the present experiment and Experiment 1, Dynamic Presentation, show that pilots familiar with European environments were sensitive to essentially the same scene features as pilots familiar with desert environments. This is not to deny that, with experience, pilots become acclimated to specific environments. Since various features occur in different quantities in different geographic regions, the acclimation process may involve an increase in the efficiency with which more prevalent features are used even though the same basic scene features are important across regions. In addition,

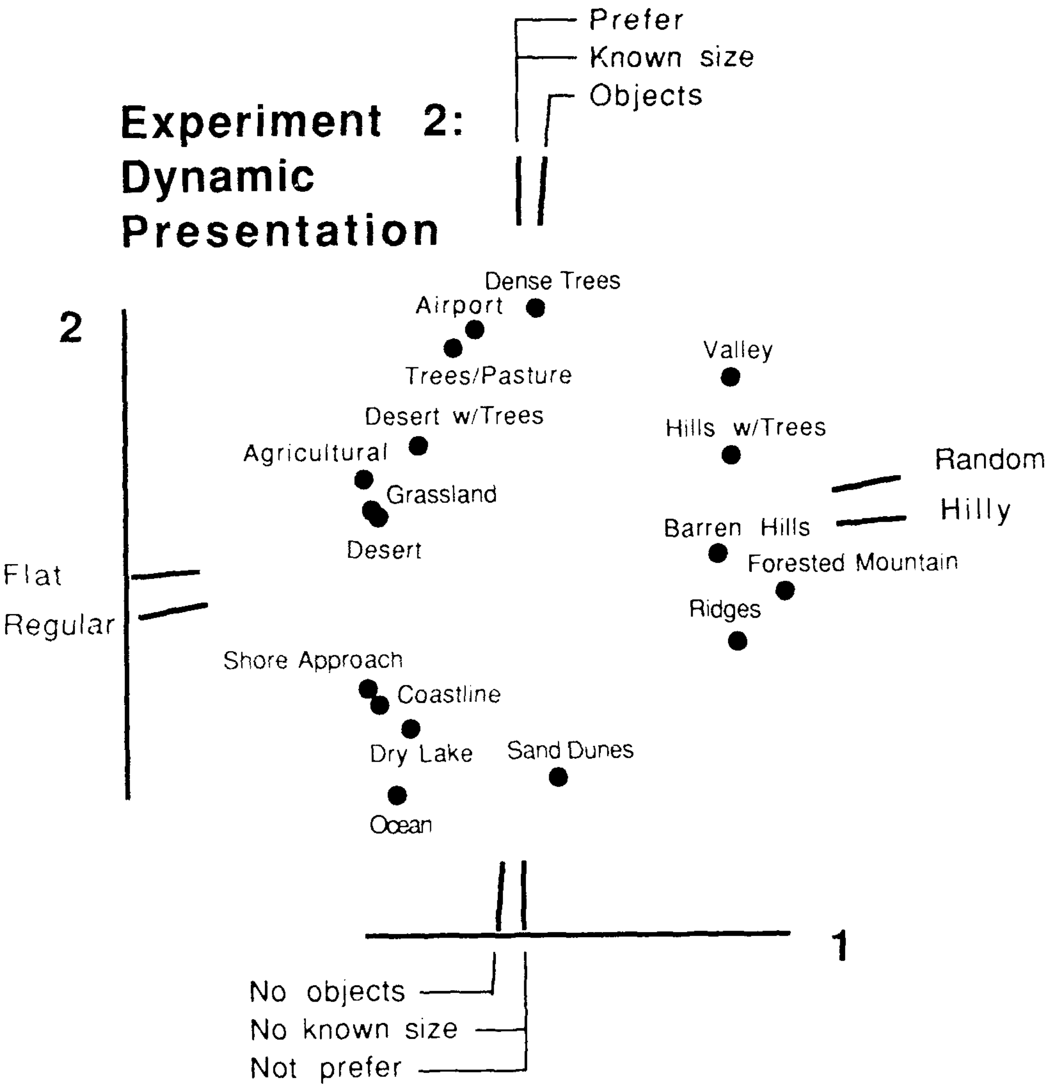


Figure 5. Two-Dimensional Spatial Configuration for Dynamic Presentation: Experiment 2.

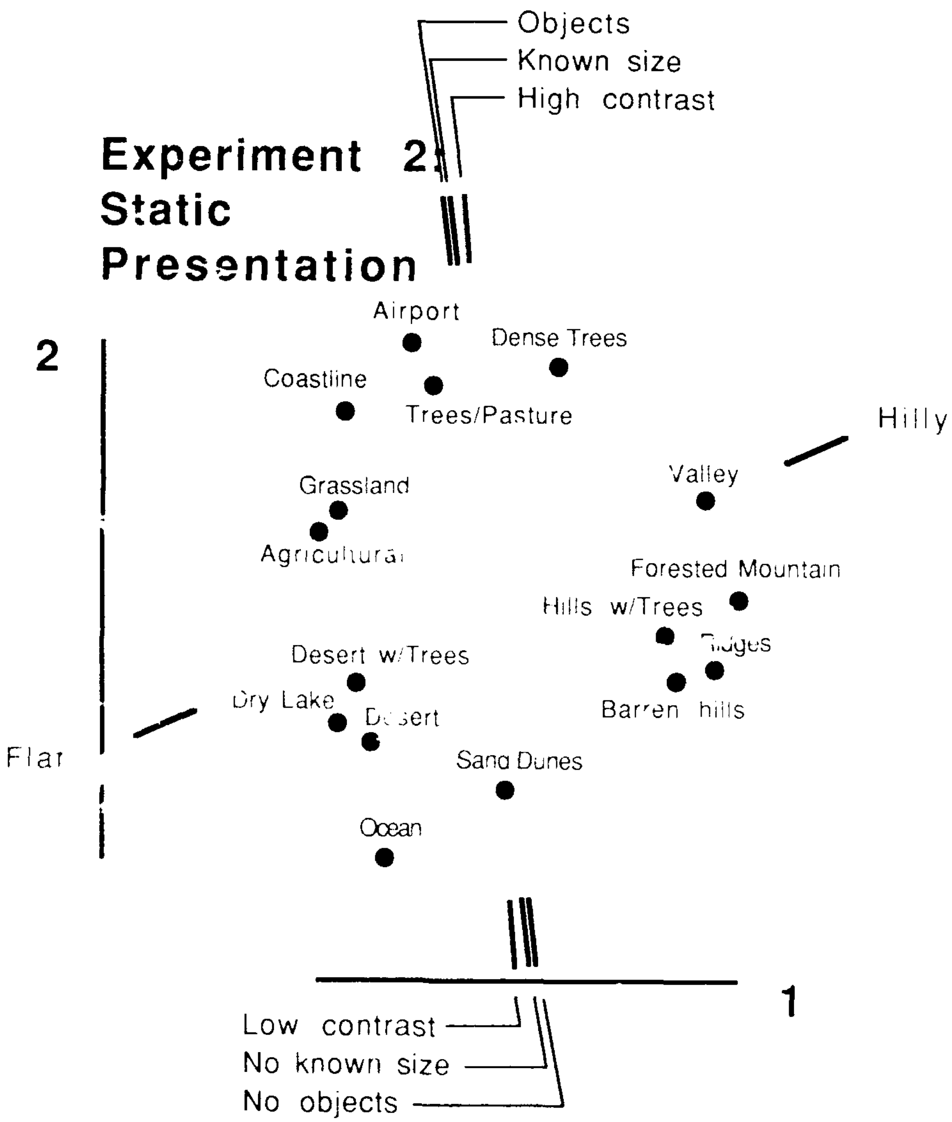


Figure 6. Two-Dimensional Spatial Configuration for Static Presentation: Experiment 2.

substantial learning of idiosyncratic cues specific to a particular region may underlie the acclimation process which would not be reflected in the present results.

Another possibility is that the present stimulus set was deficient in the type of scene feature(s) important to these pilots. The present stimulus set represents a considerably larger and more varied set than that used by Kleiss (1990) who obtained similar results. Within this fairly considerable range of stimulus variability, results have been surprisingly consistent. This fact argues that augmenting the present stimulus set with additional scenes would not substantially affect results.

Dimensional structures for Static and Dynamic Presentations were similar in the present experiment indicating that similar information was available from still photographs and videotape segments. Apart from the poorer fit of the data for Static Presentation, one important difference remained between presentation modes. Only with Dynamic Presentation did Dimension 1 account for notably more variance in similarity ratings than Dimension 2 (Table 4). Therefore, the effect of motion can be localized primarily with perception of terrain contour.

Alignment of the "Regular" property vector with Dimension 1 (Dynamic Presentation, Figure 5) pointing toward flat terrains indicates pilots judged flat terrains to be regular and predictable whereas hilly terrains were judged to be random and unpredictable. Presence of relevant scene features is typically equated with useful visual information and efficient task performance. If hills add an element of randomness and unpredictability to scenes, one may well expect that performance would suffer due to the increased demand of flying in an uncertain environment. In this sense, flat scenes should not be viewed as lacking information, but as providing more predictable information. The difference between hilly scenes and flat scenes may be especially salient to pilots accounting for the importance of this dimension in light of preference for objects captured by Dimension 2.

GENERAL DISCUSSION AND CONCLUSIONS

Perhaps most important is the consistency (with Dynamic Presentation) across experiments within the present investigation, and between these experiments and that of Kleiss (1990). Thus, there is fairly strong evidence that pilots flying at low altitudes are sensitive to variation in essentially two types of scene features: 1) terrain contour and 2) object size and spacing. One may reasonably conclude that these features should be of primary concern in flight simulators as well.

Several implications follow from these results concerning the design and use of flight simulators for training low-altitude flight.

First, the present finding that pilots were most sensitive to small-scale hills and ridges, rather than large mountains, indicates that this facet of terrain contour should be the focus of concern in flight simulator visual scenes. Terrain surfaces in flight simulators are rendered by linking polygonal surfaces together in a mosaic pattern. Terrain contour is, therefore, constrained by possible limits in the maximum number and minimum size of polygons available for this purpose. Further, unlike smoothly curved surfaces common in real-world scenes, polygons are planar surfaces joined with linear boundaries. These may introduce perceptual artifacts which do not exist in real-world scenes.

It must be emphasized that merely modeling hills and ridges in simulator scenes is not sufficient as these features must be perceptually salient to pilots to be of value. Pilots in the present experiment were sensitive to terrain contour even with Static Presentation (Experiment 2) so factors such as color and luminance contrast, and discontinuities in the gradient of texture size and density were informative with regard to shape of the terrain surface. Therefore, factors such as surface shading, atmospheric attenuation, complex texture, etc., which may affect perception of terrain contour in simulators, are all worthy of investigation. However, motion was particularly important for perception of terrain contour. In a recent review of the literature pertaining to motion perception, Stevens (1989) emphasized the role of optical flow discontinuities for perception of boundaries between foreground and background surfaces. A factor affecting perception of motion discontinuities is the density of texture elements on terrain surfaces. This implies that computer image generators (CIGs) must not only be capable of generating sufficiently dense texture on terrain surfaces, but display devices must also have sufficient resolution to display texture and to capture the small motion velocities to which humans are sensitive (Stevens, 1989, 1990). Future research should seek to define minimum requirements for factors mentioned above so that technological development may be directed toward overcoming whatever limits exist in these areas.

Previous research has shown that performance of simulated low-altitude flight tasks improves with increases in the density of objects in simulator scenes (Kleiss & Hubbard, 1991; Kleiss, Hubbard & Curry, 1989, Martin & Rinalducci, 1983). Objects in these experiments were positioned randomly on terrain surfaces forming a more or less uniform distribution of objects, at least higher densities. Scenes with high densities of uniformly spaced objects were consistently positioned near the middle of Dimension

2 in the present experiments suggesting that this is not the optimal spatial arrangement. Scenes at the extreme end of Dimension 2 contained a discontinuous distribution of objects forming regions with considerable vertical and horizontal extent (e.g., groups of trees and/or large buildings) separated by fairly large spaces. The processing demand of populating simulator scenes with high densities of small, uniformly spaced objects is considerable. Present results suggest that processing load may be reduced by using fewer objects that are larger than individual trees and bushes, or by grouping objects into high-density regions separated by relatively empty regions.

Research generally shows that training, and transfer of training, of tasks in flight simulators is best with high-detail scenes that yield highest levels of performance early in training (e.g., Lintern, Thomley-Yates, Nelson & Roscoe, 1987; Westra, 1982). The emphasis has, therefore, been on increasing simulator scene content in order to increase training efficiency. The present finding that hills and ridges add an element of randomness and unpredictability to scenes suggests that increasing scene detail by adding these features may increase task difficulty with a possible decline in task performance. However, hills and ridges are nonetheless an important feature of scenes whose effect on training bears further examination.

The structure revealed in MDS spatial configurations is a map of what is visually important to pilots in real-world scenes. As such, this structure may be taken as a standard by which simulator scenes may be assessed. For instance, if present scenes were modeled in flight simulators and the MDS methodology repeated, a similar dimensional structure should be obtained. Notable departures from this pattern, obtained consistently with real-world scenes, would point to deficiencies in flight simulator image generation and display technology. The next phase in this line of research will, therefore, be to attempt to replicate present results using simulated imagery.

REFERENCES

Academic Text: Low-Altitude Training. (1986). Tucson, AZ: 162d Tactical Fighter Group.

Barfield, W., Rosenberg, C., & Kraft, C. (1989). The effects of visual cues to realism and perceived impact point during final approach. Proceedings of the Human Factors Society 33rd Annual Meeting (pp. 115-119). Denver, CO.

Buckland, G. H., Edwards, B. J., & Stephens, C. W. (1981). Flight simulator visual and instructional features for terrain flight simulation. Proceedings of the Image Generation/ Display Conference II (pp. 351-362). Phoenix, AZ.

DeMaio, J., Rinalducci, E. J., Brooks, R., & Brunderman, J. (1983). Visual cuing effectiveness: Comparison of perception and flying performance. Proceedings of the Fifth Annual Interservice/Industry Training Equipment Conference (pp. 92-96). Washington, DC.

Harker, G. S., & Jones, P. D. (1980). Depth perception in visual simulation (AFHRL-TR-80-19). Williams Air Force Base, AZ: Operations Training Division, Air Force Human Resources Laboratory.

Isaac, P. D., & Poor, D. D. S. (1974). On the determination of appropriate dimensionality in data with error. Psychometrika, 39, 91-109.

Kleiss, J. A. (1990). Terrain visual cue analysis for simulating low-level flight: A multidimensional scaling approach (AFHRL-TR-90-20). Williams AFB, AZ: Operations Training Division, Air Force Human Resources Laboratory.

Kleiss, J. A., Hubbard, D. C., & Curry, D. G. (1989). Effect of three-dimensional object type and density in simulated low-level flight (AFHRL-TR-88-66, AD A209 756). Williams AFB, AZ: Operations Training Division, Air Force Human Resources Laboratory.

Kleiss, J. A., & Hubbard, D. C. (1991). Effect of two types of scene detail on detection of change in altitude in a flight simulator (AL-TR-1991-0043). Williams Air Force Base, AZ: Aircrew Training Research Division, Armstrong Laboratory.

Kruskal, J. B., & Wish, M. (1978). Multidimensional Scaling. Sage University Paper Series on Quantitative Applications in the Social Sciences, 07-011. Beverly Hills and London: SAGE Publications, Inc.

Lintern, G., Thomley-Yates, K. E., Nelson, B. E., & Roscoe, S. N. (1987). Content, variety, and augmentation of simulated visual scenes for teaching air-to-ground attack, Human Factors, 29, 45-59.

Martin, E. L., & Rinalducci, E. J. (1983). Low-level flight simulation vertical cues (AFHRL-TR-83-17, AD A133 612). Williams Air Force Base, AZ: Operations Training Division, Air Force Human Resources Laboratory.

McCormick, D., Smith, T., Lewandowski, F., Preskar, W., & Martin, E. (1983). Low-altitude database development evaluation and research (LADDER). Proceedings of the Fifth Interservice/ Industry Training Equipment Conference (pp. 150-155). Washington, DC.

Nygren, T. E. (personal communication, November, 1990).

Owen, D. H., Warren, R., Jensen, R. S., & Mangold, S. J. (1981). Optical information for detecting loss in one's own altitude. In D. H. Owen & R. S. Jensen (Eds.), Methodological approaches to identifying relevant features for visual flight simulation (Final Technical Report for AFOSR Contract No. F49620-79-C-0070, Task 1). Columbus, OH: The Ohio State University, Department of Psychology, Aviation Psychology Laboratory.

Owen, D. H., Warren, R., Jensen, R. S., Mangold, S. J., & Hettinger, L. J. (1981). Optical information for detecting loss in one's own forward speed. Acta Psychologica, 48, 203-213.

Reardon, K. A. (1988). The effects of nested texture on a landing judgment task. Proceedings of the Human Factors Society 32nd Annual Meeting (pp. 10-14). Anaheim, CA.

Schiffman, S. S., Reynolds, M. L., & Young, F. W. (1981). Introduction to multidimensional scaling: Theory, methods, and applications. New York, NY: Academic Press, Inc.

Stevens, K. A. (personal communication, December 20, 1989).

Stevens, K. A. (personal communication, August 5, 1990).

Westra, D. P. (1982). Simulation and training for aircraft carrier landings: An economical multifactor approach. Proceedings of the Human Factors Society 26th Annual Meeting (pp. 830-834). Seattle, WA.

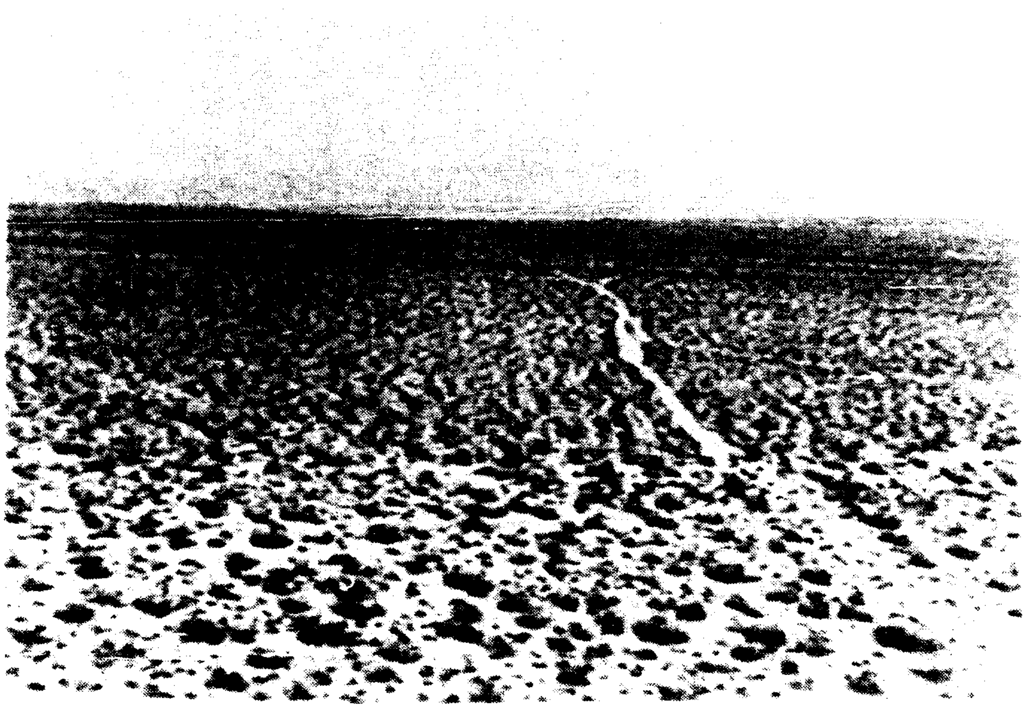
Wolpert, L. (1988). The active control of altitude of differing texture. Proceedings of the Human Factors Society 32nd Annual Meeting (pp. 15-19). Anaheim, CA.

Young, F. W., Takane, Y., & Lewyckyj, R. (1978). ALSCAL: A nonmetric multidimensional scaling program with several differences options. Behavior Research Methods & Instrumentation, 10, 451-453.

APPENDIX A

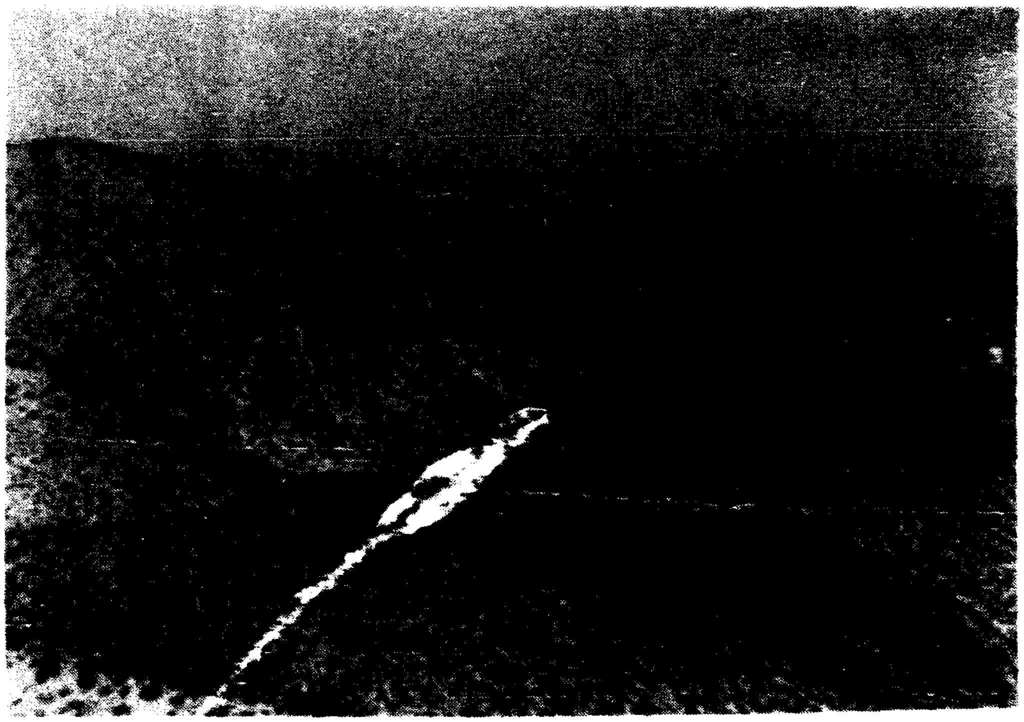
REPRESENTATIVE FRAMES FROM THE SEVENTEEN VIDEO SEGMENTS

Airport



Desert

Dry Lake



Ridges

Trees/Pasture

Dense Trees

Valley

Forested Mountain

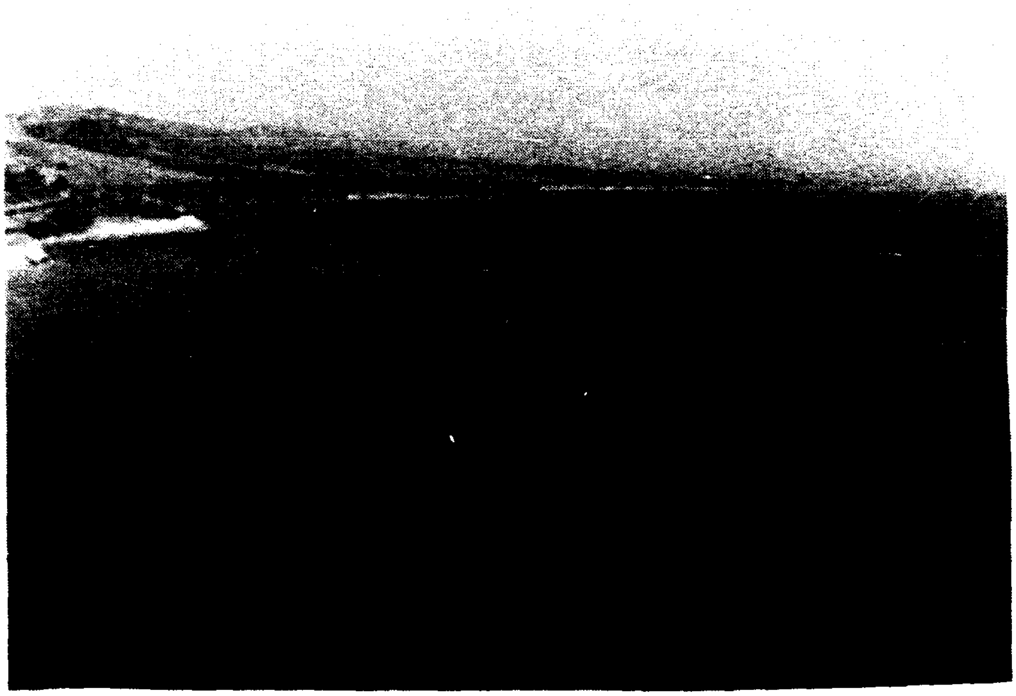
Hills w/Trees

Barren Hills

Sand Dunes

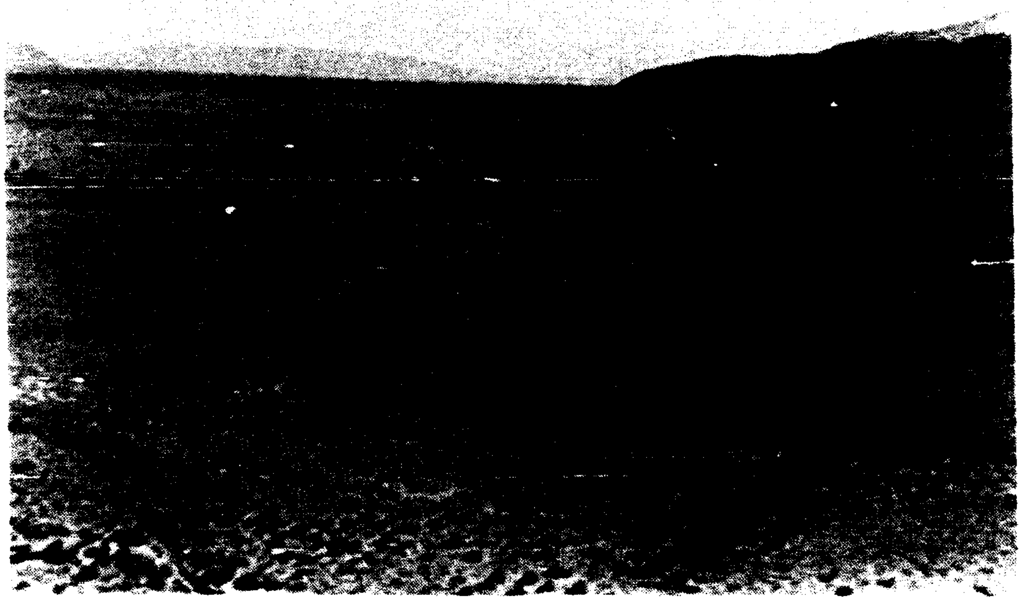
Desert w/Trees

Ocean



Coastline

Agricultural



Grassland

Shore Approach

APPENDIX B

INSTRUCTION PAGE

During this investigation you will be judging how similar or different a number of terrains are in terms of visual cues for visual low-level flight. The terrains are represented in photographs that were each shot at approximately 125 feet AGL. Imagine how the terrains would appear to you if you were flying over them at the depicted altitude. You will be comparing the terrains two at a time. For each pair of terrains a line will be provided upon which to place a mark. Below is an example:

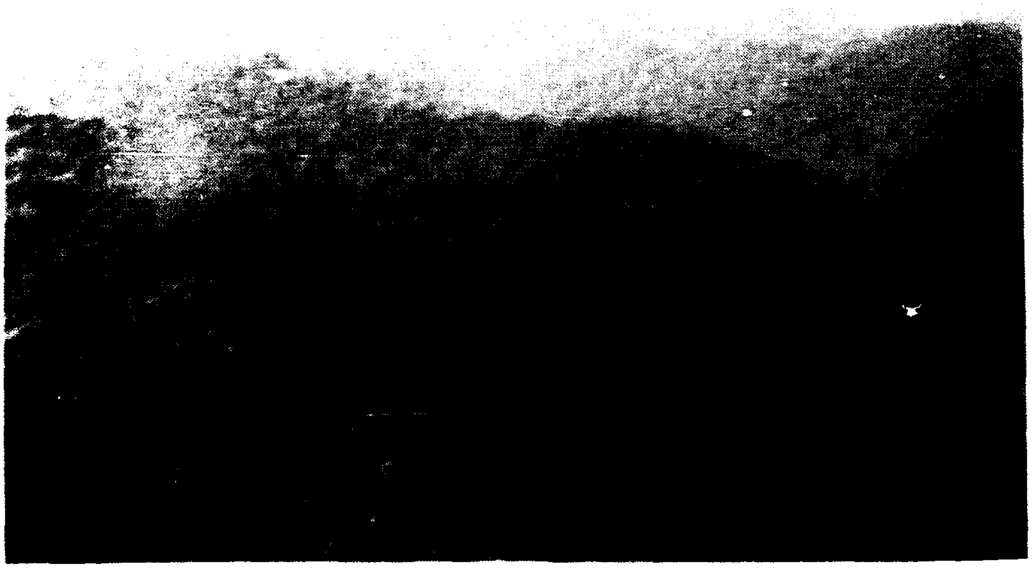
Exact same _________________________________ Completely different

If the two terrains appear identical, then place a mark at the end of the line by Exact same. If you find that there is a difference, place a mark somewhere along the line showing how much difference. Completely different is in the context of this particular group of terrains, so try to use the entire range that is available on the lines. It is not necessary to scrutinize the terrains or attempt to identify specific terrain characteristics that affect your judgments; a general impression of similarity is fine. In order to get an idea how much difference there is in this group of terrains, you will be allowed to view the individual photographs before beginning.

One thing to remember is that different people judge things in different ways. Therefore there are no right or wrong answers. Two terrains may appear very similar to one person and quite different to another. Both results are important. However, please confine your judgments to terrain characteristics or visual cues that are relevant for controlling altitude in visual low-level flight. We are not interested in navigational features, for example, or esthetics.

APPENDIX C

FORESTED MOUNTAIN TERRAIN: EXPERIMENT 2



Forested Mountain (Experiment 2)

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